Groundwater Modeling to Inform Water Resource Mitigation


Teanaway River; Washington Water Trust

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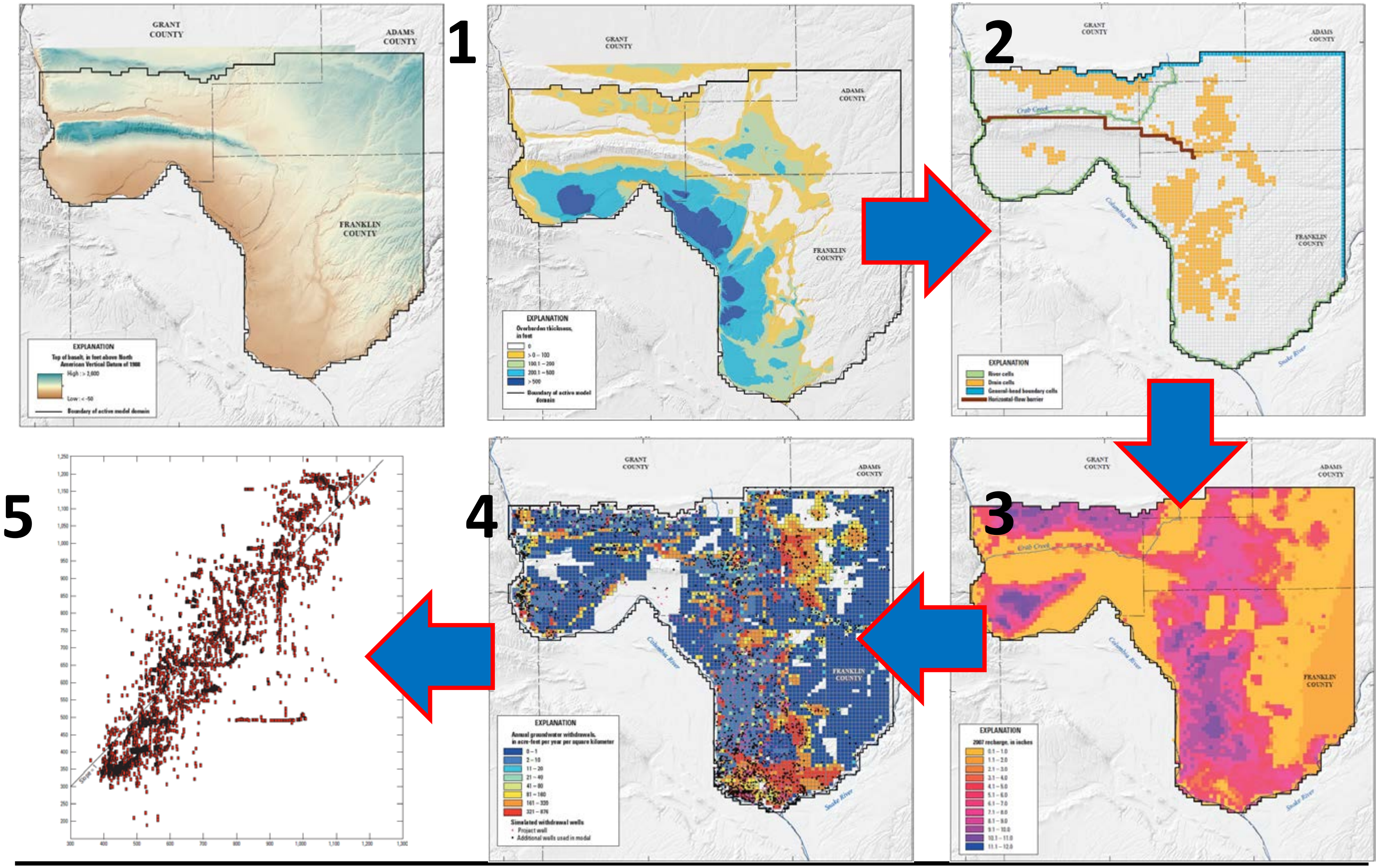
Today's presentation

- Primer on numerical groundwater modeling
- Limitations (and benefits) of using groundwater models to inform water-resource mitigation
- What USGS has been doing to increase the usefulness of our groundwater models
- What our federal, tribal, state, local partners want to know from groundwater models
  - Selected findings regarding groundwater use and streamflow impacts from around the state

Building a numerical groundwater flow model



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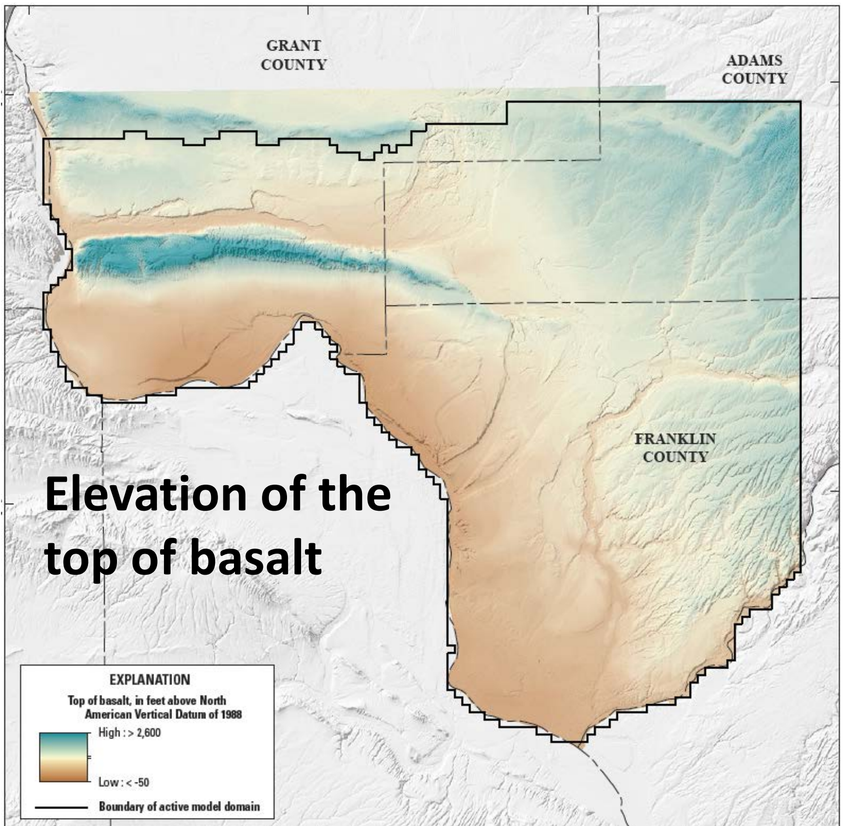
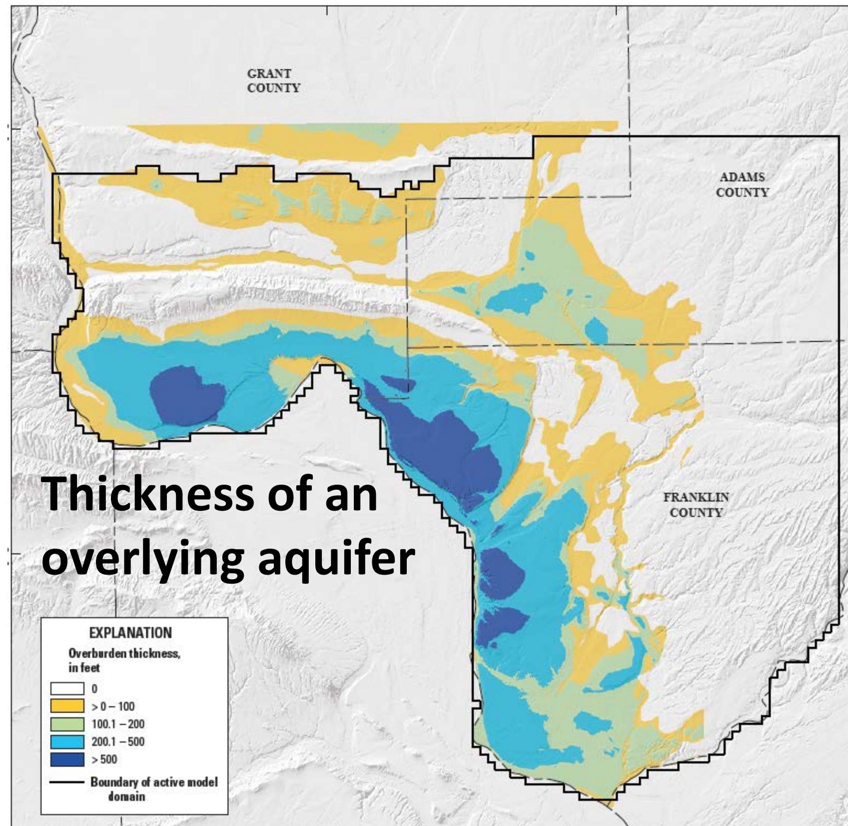
1 - Map the hydrogeologic framework

- Based on surface geology maps, available well logs
- Locate wells on the ground and associate with a drillers log
- Establish a water-level monitoring network, run for ~1-2 years

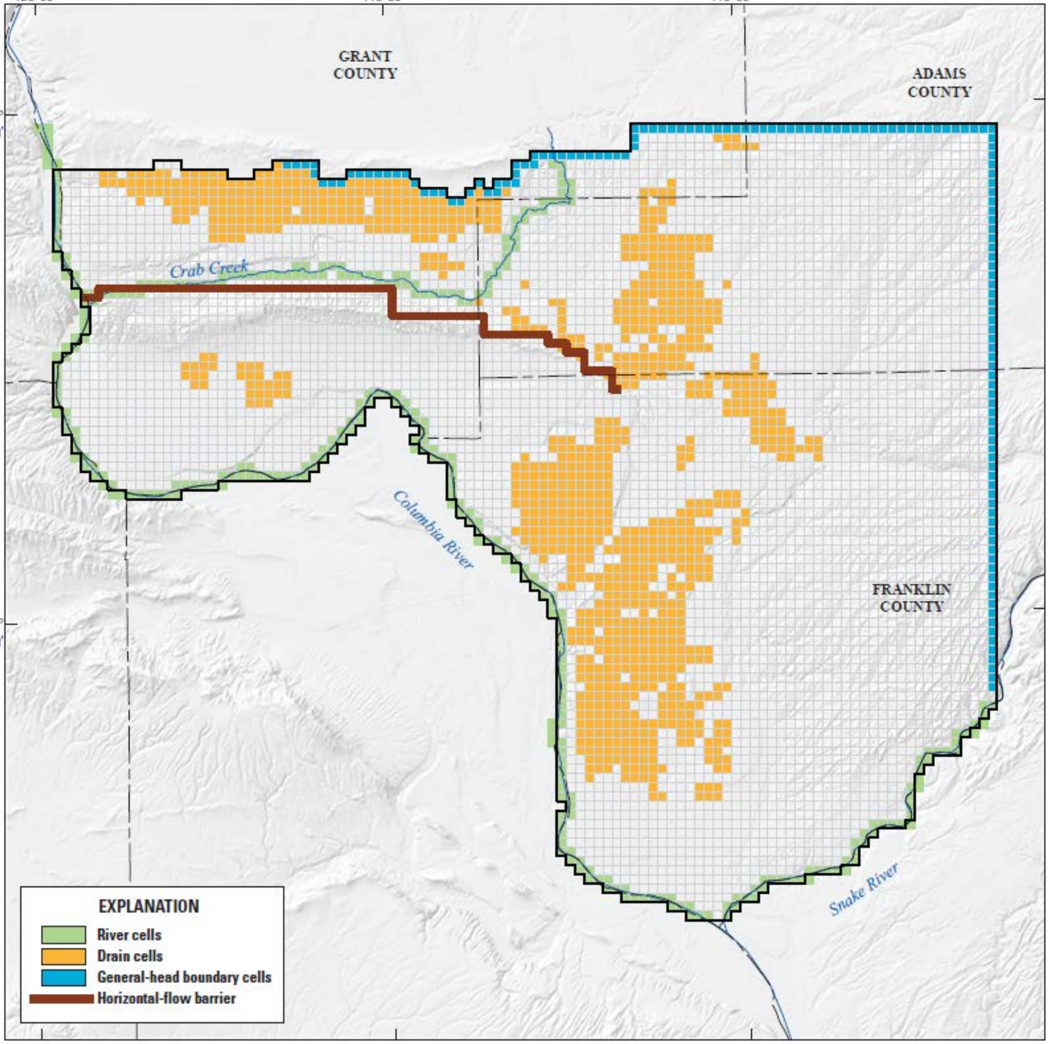




Example for East Pasco Basin: U.S. Geological Survey Scientific Investigations Report 2016–5026

2 – Create model grid, boundaries, features

- Grid represents the real world with discrete volumes (model cells) with uniform properties
- Boundary conditions define allowable flows into/out of the model domain
- Features include streams, springs, rivers, agricultural drains, etc. that we want to include

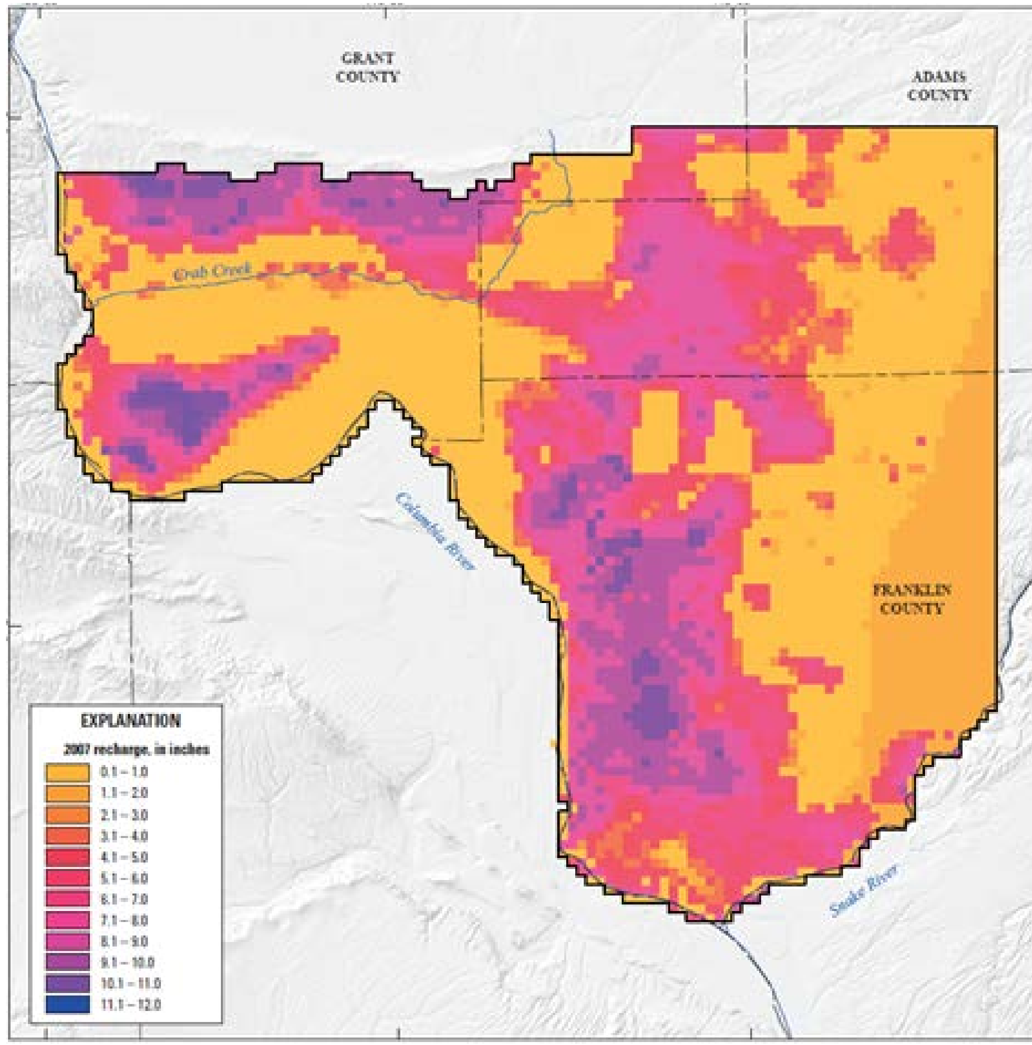


3 – Specify water going into the model

Groundwater recharge from precipitation, and "return flows"

- Drainage beneath irrigated lands
- leaky canals
- septic systems

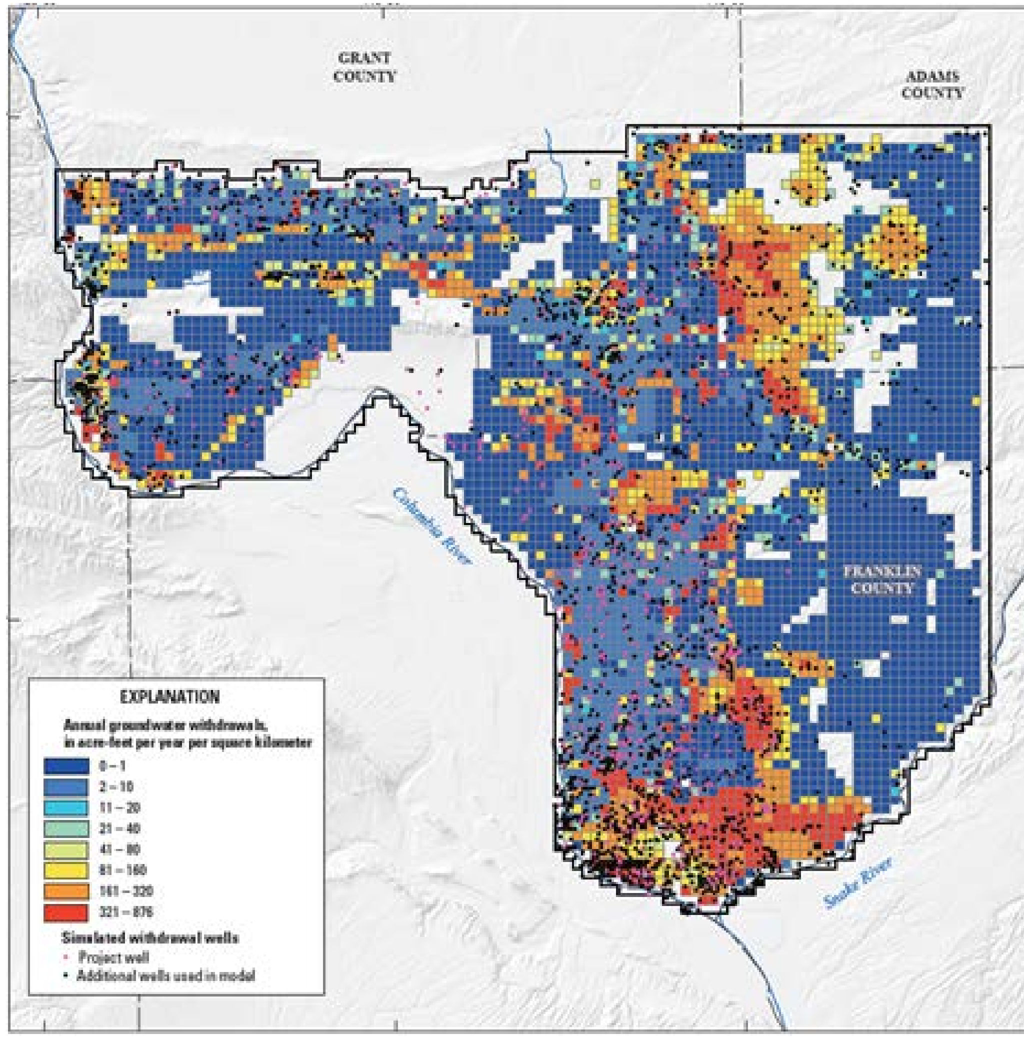
Recharge that depends on groundwater levels is not specified; it is calculated by the model



4 – Specify groundwater withdrawals

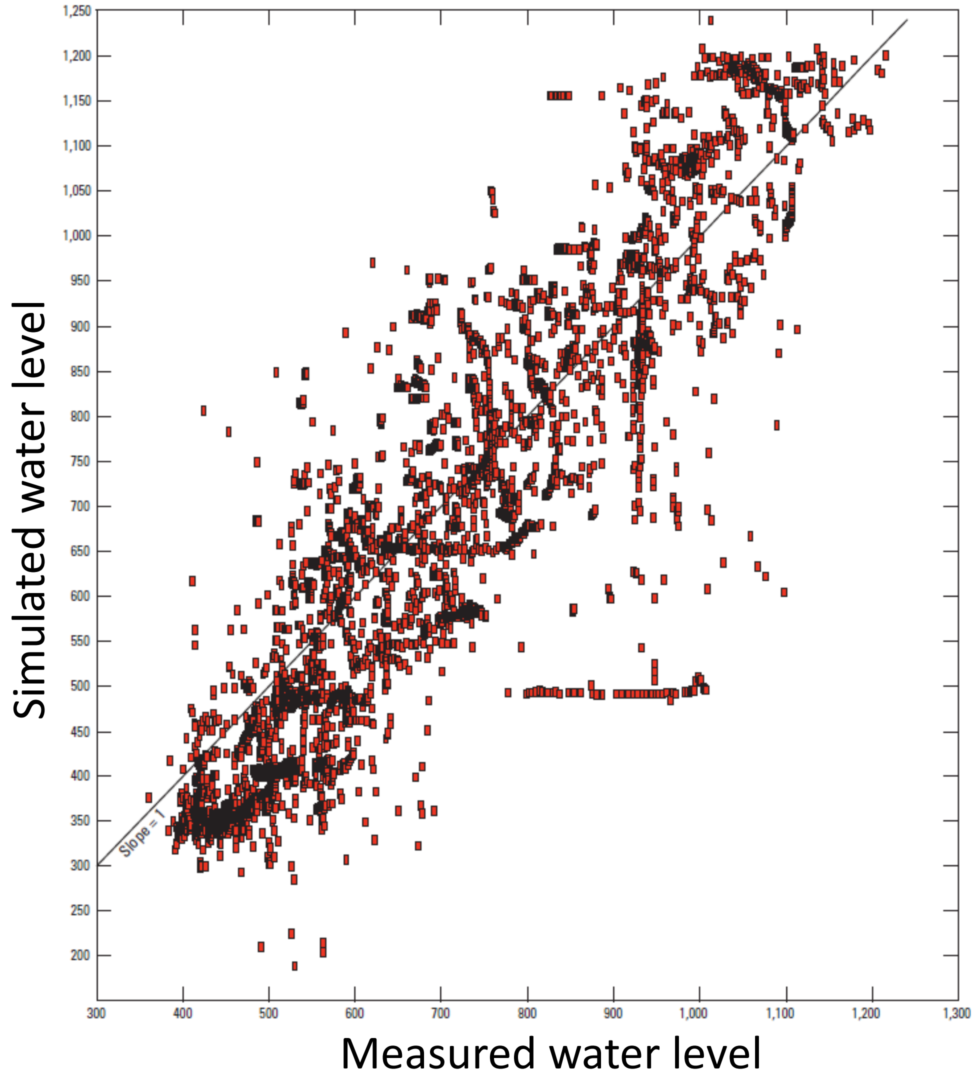
Amounts withdrawn (not necessarily used) by:

- Domestic wells
- Municipal wells
- Irrigation wells



5 – Calibrate the model

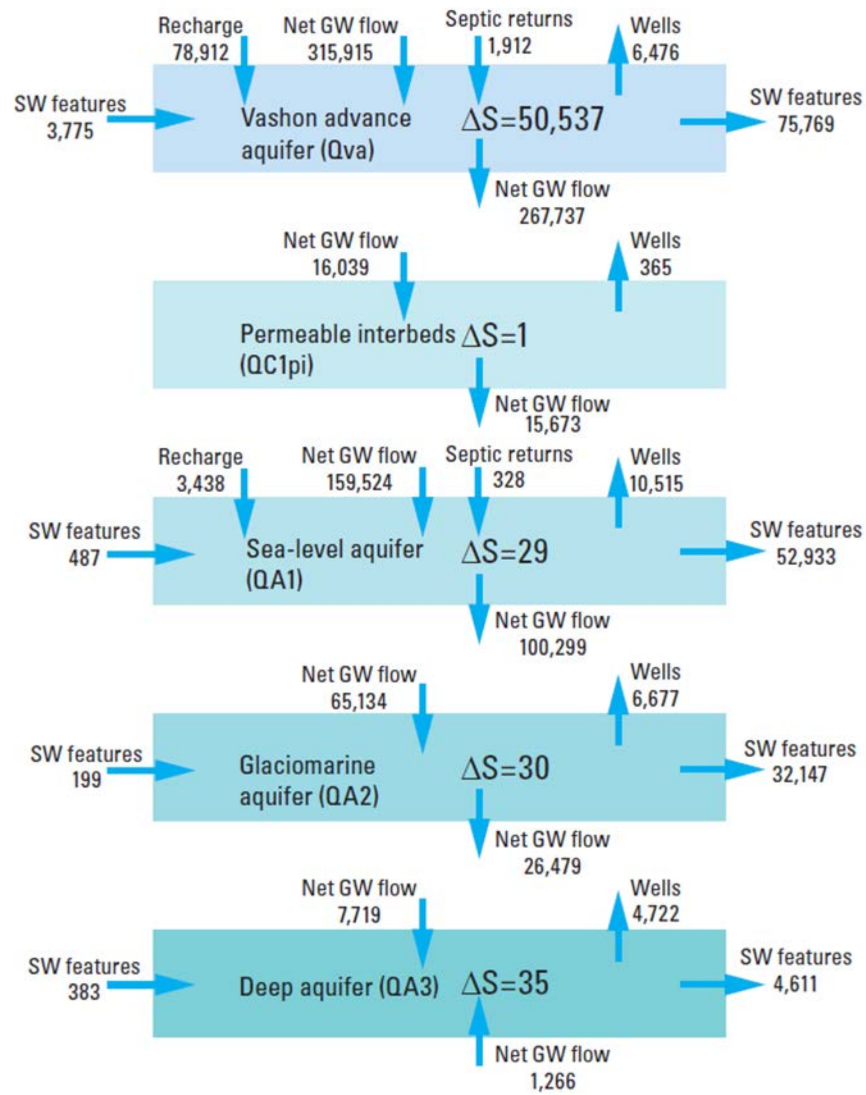
- Adjust model parameters (for all cells) to control how readily water flows or how much is stored to best match measured
  - water levels
  - streamflow rates
- Highly automated process (inverse modeling) that also tells us what the model is most "sensitive" to and the uncertainty of results



Finally, we have a model to use

- First application is usually a groundwater budget, both simple or complex (Kitsap 2012 groundwater budgets)

Water-budget component	Acre-feet	Percent
Groundwater recharge		
From precipitation	664,610	97
From return flows	22,122	3
Total	686,732	100
Fate of recharge		
Discharge to streams	455,550	66
Other natural discharge	200,316	30
Withdrawals from wells	30,866	4
Total	686,732	100



Kitsap model GW budget

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Limitations and benefits of models

"Essentially, all models are wrong,
but some are useful."[1]

- Models are wrong because they are simplifications of reality
- Some models, especially in the "hard" sciences (such as hydrology), might be only a little wrong…
  - The cause and effect are right, but the size of the effect is less certain
  - Aquifer system behavior is correct, but the many local-scale details and variations of the system are not captured
- The models are certainly useful
  - Simplifications of reality help us explain and understand all the interactions between what we have measured and observed
  - The models give us an idea of how complicated systems might respond to future conditions (more pumping, warmer climate, less recharge)

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[1]G.E. Box and N.R. Draper (1987). Empirical Model-Building and Response Surfaces

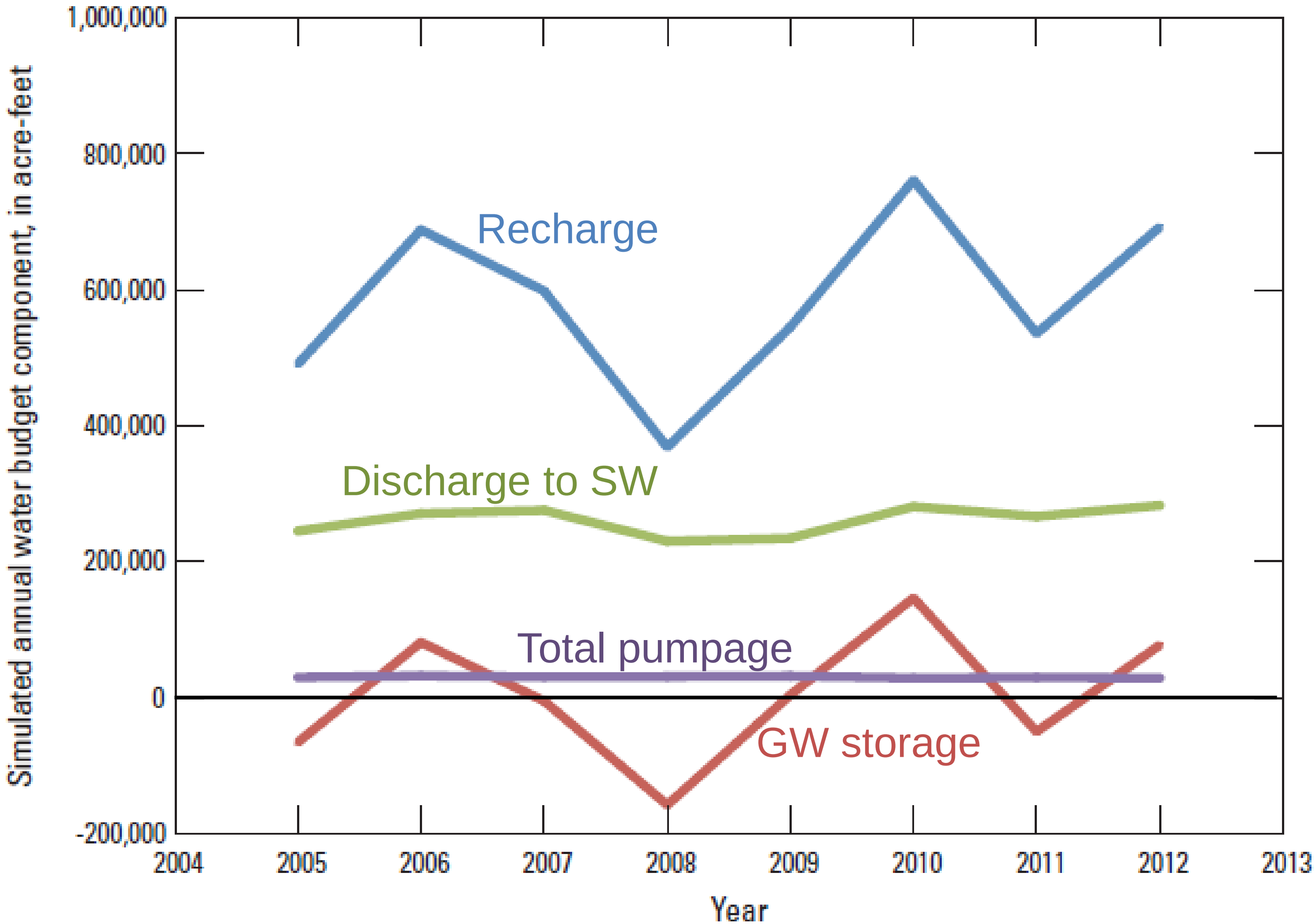
Making our groundwater models useful

- Convene technical committee with partner representatives
  - Great sources of local data and understanding (boots on the ground)
  - True partners to help decide the trade-offs in model construction
  - Allows us to better manage expectations
  - Lead the crafting of scenarios for the model to inform
- Construct models as simple as possible…and as detailed as needed
- Peer review for credibility
  - Through USGS Fundamental Science Practices
- Model dissemination
  - Well structured archive publicly available immediately at publication
  - Partners and their consultant are familiar with the models

Selected findings from groundwater models

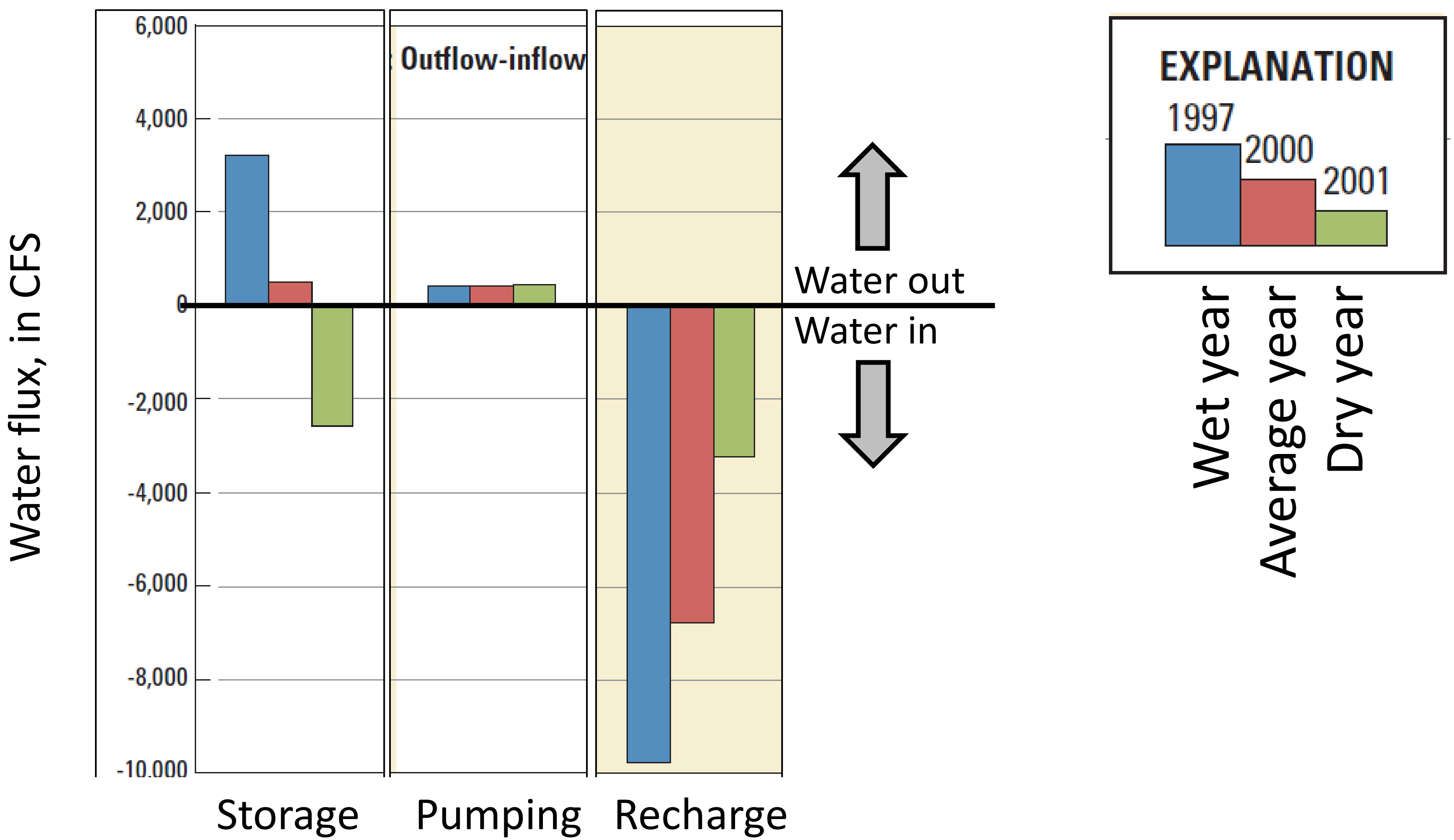
- The most significant variation in water levels and groundwater discharge to streams is due to variations in recharge
  - Year to year and even cumulative changes due to pumping are much less than changes due to year to year variation in recharge
  - Monitoring the long-tem effectiveness of mitigation under ESSB 6091 will be challenging

Kitsap Peninsula groundwater budgets



Refs: USGS Scientific Investigation Reports 2016–5052

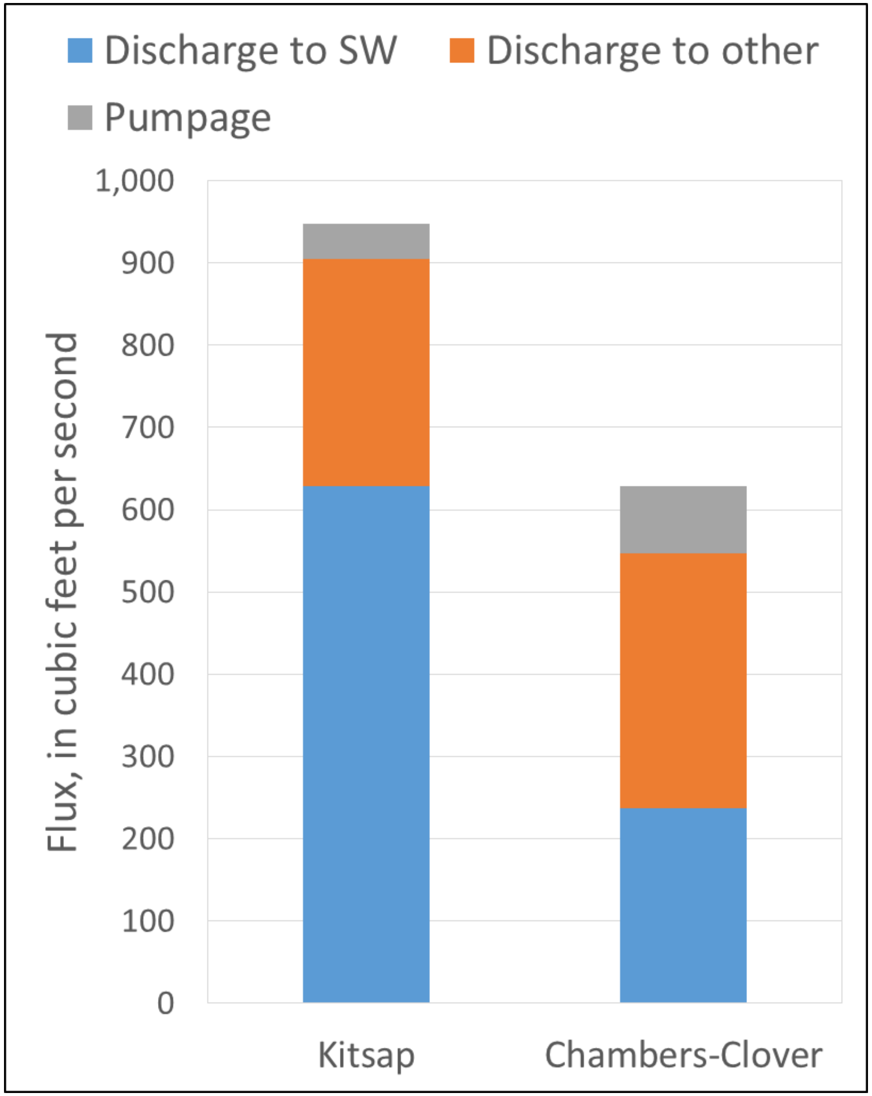
Yakima Basin groundwater budgets

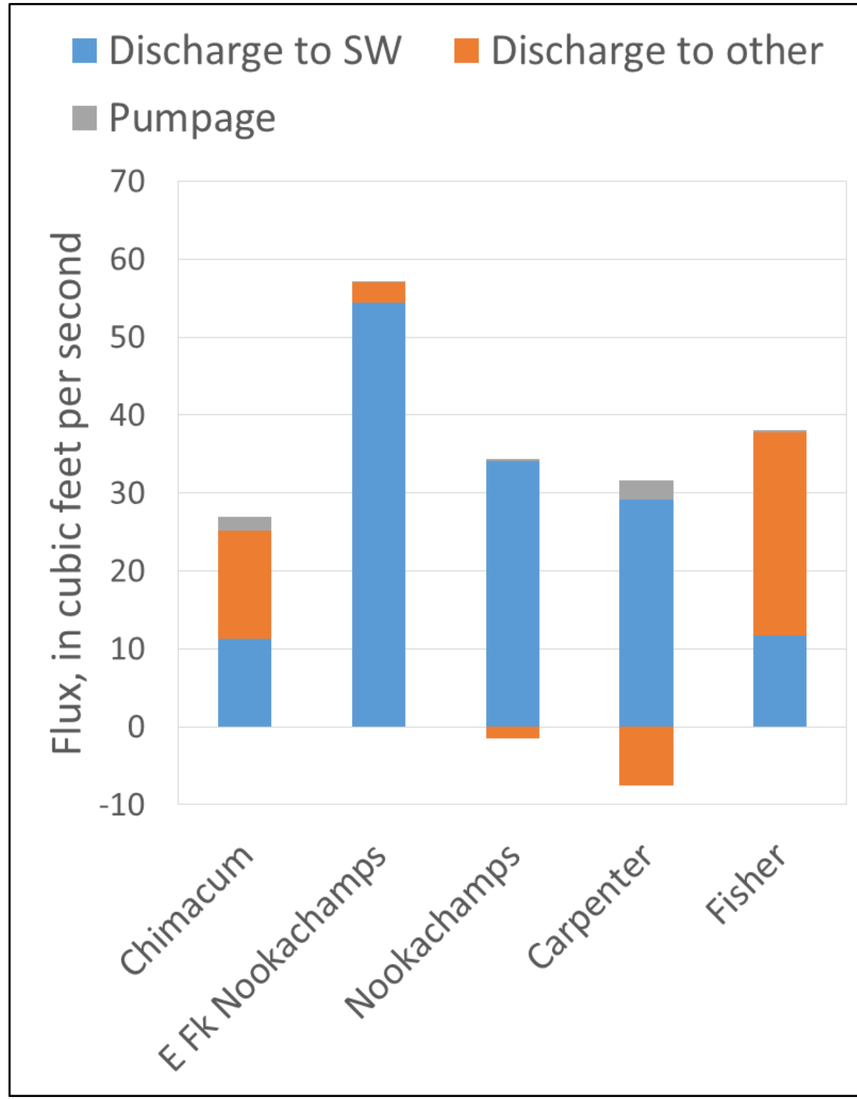


Selected findings from groundwater models

- Pumping is often a relatively small component of a basin's groundwater budget, but…
  - Models show it can still have significant effects (increases and decreases) on seasonal streamflows in small basins
  - Modest increases in shallow groundwater discharge to streams is not uncommon if pumping is from deeper aquifers (increased return flow)
  - Any increase in pumping (and consumptive use) will be accompanied by an equivalent decrease in groundwater storage, or discharge to somewhere (often Puget Sound)

Significance of pumping in groundwater budgets





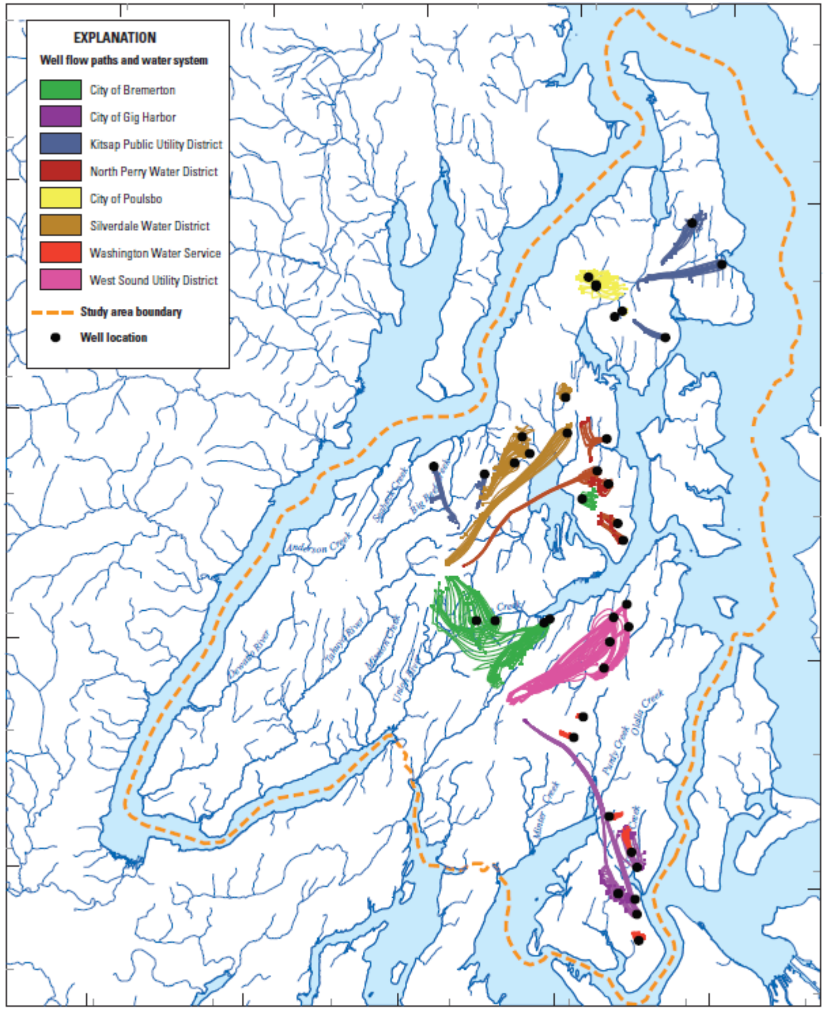
Refs: USGS Scientific Investigation Reports 2009-5270, 2010-5184, 2010-5055, 2011-5086, 2013-5160, 2016–5052

Selected findings from groundwater models

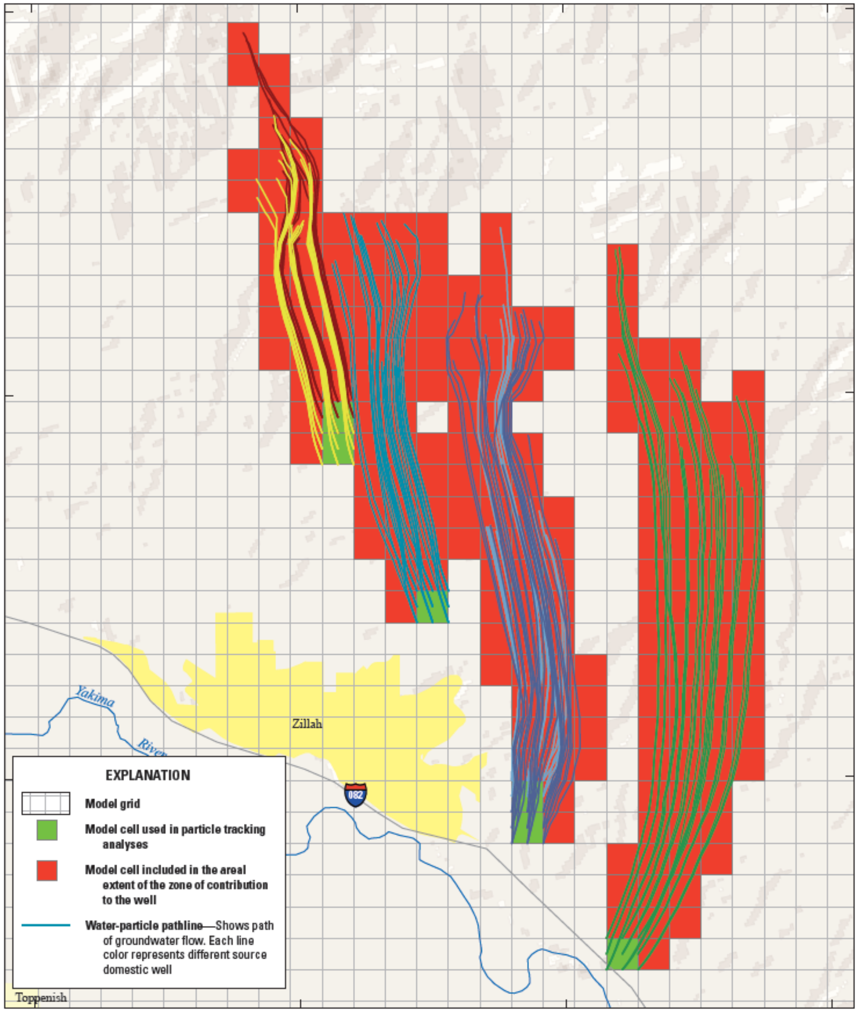
- Recharge areas for water-supply wells are complicated and often non-intuitive
  - Particle tracking with a numerical model reflects the complexity of complicated, layered aquifer systems
  - The complexities of these recharge areas are indicative of the complexities of capture zones of streamflow by pumping wells

Model-derived recharge areas for wells

Municipal wells on Kitsap Peninsula



Domestic wells in lower Yakima Basin



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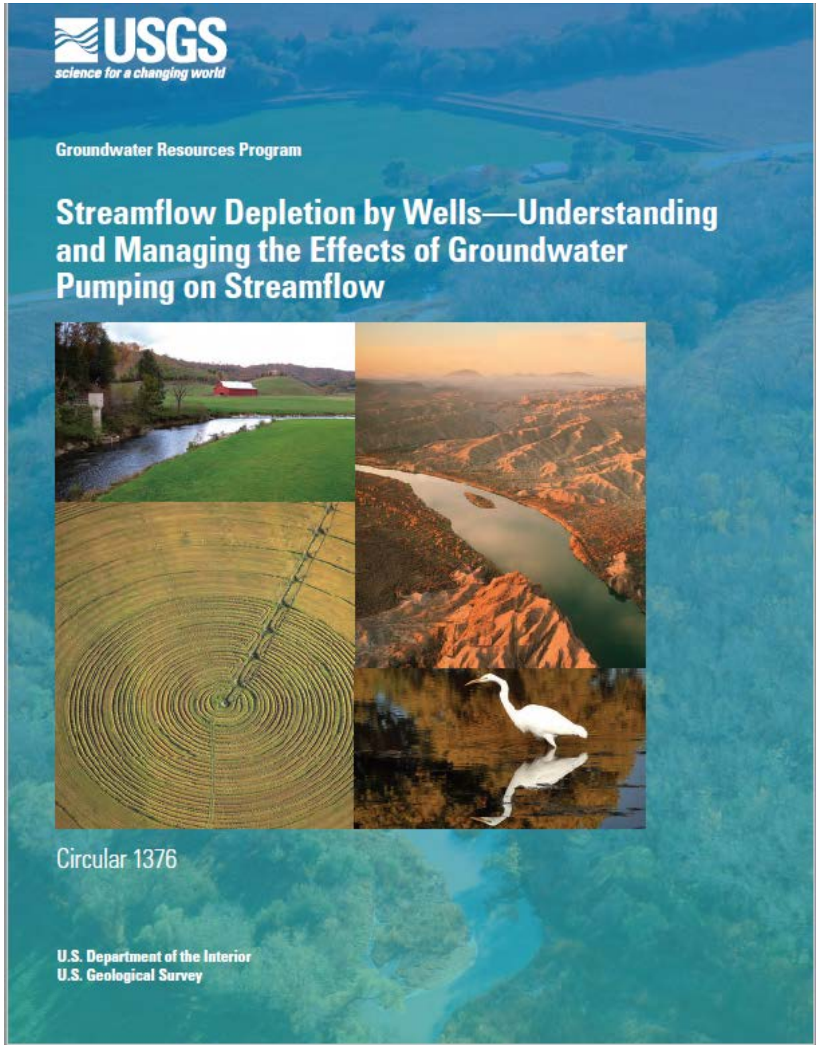
Other types of groundwater models

- Numerical models are perhaps the best, but not the only, tool to evaluate mitigation strategies
  - Analytical models are limited to analyses of idealized conditions where complexities of a real groundwater system cannot be accounted for
  - Numerical models provide the most robust approach for determining rates, locations, and timing of streamflow depletion by wells at the WRIA scale.



Current and ongoing work by USGS

- Southeast Sound (SES) groundwater model under construction
  - Includes lower Puyallup and Chambers-Clover basins
- Collaborating with Dept of Ecology on implementation plans under ESSB 6091
  - Technical review of guidelines to planning entities
- Puget Sound Action Agenda Near-Term Action on groundwater and summer low flows
  - Constructing groundwater budgets for all lowland Puget Sound basins
  - Focus extends beyond ESSB 6091 to <u>all</u> groundwater uses with an eye on population growth, urbanization, and climate change

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Fish Trap Creek, Photo by Steve Cox